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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF THE EFFECTS OF A PADDLE BALANCE ON THE CONTROL CHARACTERISTICS AT TRANSONIC SPEEDS OF A TAPERED 45.58° SWEPTBACK WING OF ASPECT RATIO 3 HAVING A FULL-SPAN FLAP-TYPE CONTROL

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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF THE EFFECTS OF A PADDLE BALANCE ON THE CONTROL CHARACTERISTICS AT TRANSONIC SPEEDS OF A TAPERED 45.58° SWEPTBACK WING OF ASPECT RATIO 3 HAVING A FULL-SPAN FLAP-TYPE CONTROL

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SUMMARY

A preliminary investigation was made in the Langley high-speed 7- by 10-foot tunnel on a 45.58° sweptback wing to determine the effects of a paddle balance on the control characteristics of a full-span flap-type control. The tests were made through the transonic speed range at a Reynolds number of approximately 1,000,000, utilizing the high-velocity flow field over a reflection plate mounted on the side wall of the tunnel. The wing had an aspect ratio of 3, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. The data indicated that the paddle balance was capable of reducing the hinge moments of the flap throughout the speed range investigated with little effect on the lift and rolling-moment characteristics.

INTRODUCTION

Excessive control hinge moments, associated with the high speeds at which present-day aircraft operate, have necessitated the extensive use of powered control systems. Although powered systems have proved adequate, manually operated controls are desirable. The National Advisory Committee for Aeronautics is currently investigating several possible means of aerodynamically balancing excessive control hinge moments encountered in the transonic speed range. Since very few transonic hinge-moment data applicable to balancing controls aerodynamically are available, an exploratory investigation was initiated in an attempt to establish a basis for further study of the problem.

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This paper presents the results of a preliminary investigation at transonic speeds in the Langley high-speed 7- by 10-foot tunnel on a wing with quarter-chord line swept back 45.58°, an aspect ratio of 3, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. The model was tested with a full-span, plain, flap-type control with and without a paddle balance. A paddle balance consists of two lifting surfaces, one of which is attached to the upper surface of the flap and the other to the lower surface of the flap by means of booms that extend outward from the chord plane and ahead of the flap hinge line. The results are given for a flap deflection range of ±10° through a Mach number range of 0.70 to 1.10, at angles of attack from -4° to 16°. The Reynolds number of the tests varied from about 950,000 to 1,050,000. The configuration is not necessarily the optimum paddle size, shape, or location.

COEFFICIENTS AND SYMBOLS

C_L	lift coefficient (Twice semispan lift/qS)
C_l	gross rolling-moment coefficient at plane of symmetry (Rolling moment of semispan model/qSb)
C_h	total flap hinge-moment coefficient (Flap hinge moment about hinge line of flap/q2M^1)
S	twice wing area of semispan model, 0.202 square foot
b	twice semispan of model, 0.778 foot
$\bar{c}$	mean aerodynamic chord of wing, 0.269 foot $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$
M^1	area moment of flap rearward of the hinge line about the hinge line, 0.000692 foot^3
q	effective dynamic pressure over span of model, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
c	local wing chord, feet
y	spanwise distance from plane of symmetry
ρ	mass density of air, slugs per cubic foot

V free-stream velocity, feet per second

M effective Mach number over span of model $\left(\frac{2}{S}\int_0^{b/2} cM_a\, dy\right)$

M_a average chordwise local Mach number

M_l local Mach number

R Reynolds number of wing based on $\bar{c}$

α angle of attack, degrees

δ flap deflection relative to wing-chord plane, measured in a plane perpendicular to flap hinge axis (positive when trailing edge is down), degrees

Parameters:

$$C_{h_\alpha} = \left(\frac{\partial C_h}{\partial \alpha}\right)_\delta$$

$$C_{h_\delta} = \left(\frac{\partial C_h}{\partial \delta}\right)_\alpha$$

$$C_{L_\alpha} = \left(\frac{\partial C_L}{\partial \alpha}\right)_\delta$$

$$C_{L_\delta} = \left(\frac{\partial C_L}{\partial \delta}\right)_\alpha$$

$$C_{l_\delta} = \left(\frac{\partial C_l}{\partial \delta}\right)_\alpha$$

The subscripts outside the parentheses indicate the factors held constant during the measurement of the parameters in the vicinity of $\delta = 0^\circ$ and $\alpha = 0^\circ$.

MODEL AND APPARATUS

The semispan model used during this investigation was tested on the side-wall reflection plane of the high-speed 7- by 10-foot tunnel and had a quarter-chord sweep angle of 45.58°, an aspect ratio of 3.0, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. Pertinent dimensions of the model and the reflection-plane plate are given in figure 1. The wing was equipped with a full-span, plain, flap-type control of 25.4 percent of the chord measured parallel to the plane of symmetry. The flap was tested with and without a paddle balance, which consisted of two sharp-edged 60° triangular lifting surfaces, one of which was attached to the upper surface of the flap and the other to the lower surface of the flap by booms that extended 0.28c outward from the chord plane and 0.17c ahead of the flap hinge line, measured to the centroid of the paddle (fig. 2). The paddle balance was mounted at the 0.50-semispan station of the flap and had an area equal to 9.1 percent of the flap area.

The steel model was mounted on an electrical strain-gage balance which was attached to the tunnel wall and shielded from the wind stream. A strain-gage beam was attached to the flap hinge-pin and was used to indicate the flap hinge moments. The model butt extended through a turntable in the reflection-plane plate. The clearance gap, about 1/16 inch, between the model butt and the turntable was sealed by a sponge-rubber wiper seal, glued to the lower surface of the turntable (reference 1). A photograph of a typical model installation on the side-wall reflection plane is presented in figure 3.

TESTS

The tests were made on the side-wall reflection plane of the Langley high-speed 7- by 10-foot tunnel. The reflection-plane test setup was devised as a method of testing small semispan models through the transonic speed range and utilized the high-velocity flow field over a plate mounted about 3 inches from the tunnel wall. The technique is further described in reference 2.

Typical contours of local Mach number distribution in the vicinity of the model are shown in figure 4. The contours indicate a Mach number variation over the model of as much as 0.05 at high Mach numbers. No attempt has been made to evaluate the effects of this Mach number variation on the force measurements. The effective test Mach number was obtained from similar contour charts by use of the relationship

$$M = \frac{2}{S}\int_0^{b/2} cM_a \, dy$$

Lift, rolling-moment, and control hinge-moment data were obtained through a Mach number range of 0.70 to 1.10 and angle-of-attack range of -4° to 16°. A flap deflection range of $\pm 10^\circ$ was investigated for the plain flap and the flap equipped with a paddle balance. The variation of average Reynolds number with Mach number is presented in figure 5; the Reynolds number varied from about 950,000 to about 1,050,000.

CORRECTIONS

A reflection-plane correction, which accounts for the carry-over of load to the other wing, has been applied to the parameter C_{l_δ} throughout the Mach number range tested. The correction factor $C_{l_\delta} = \left(C_{l_\delta}\right)_{measured} \times 0.672$ which was applied to the data was obtained from an unpublished investigation at low speeds ($M = 0.25$). The control effectiveness parameter C_{l_δ} presented herein represents the aerodynamic effects on a complete wing produced by the deflection of a control on only one semispan of the complete wing. Although the corrections are based on incompressible conditions, it is believed that the results obtained by applying the correction factor give a better representation of the true conditions than the uncorrected results.

The design of the wing necessitated the use of a long hinge-pin extension to accommodate the hinge-moment strain-gage beam. Measurable deflections in torsion were evident when control hinge moments were applied. These deflections were found to be a direct function of the hinge moment applied, and control deflections have been corrected accordingly.

RESULTS AND DISCUSSION

Presentation of Results

The results of this investigation are presented in the figures indicated in the following outline:

The slopes presented in figures 14 to 16 were measured in the vicinity of $\alpha = 0^{\circ}$ and $\delta = 0^{\circ}$.

Hinge-Moment Characteristics

The hinge-moment parameters $C_{h_{\delta}}$ and $C_{h_{\alpha}}$ (fig. 14) show that a paddle balance provided material reductions in $C_{h_{\delta}}$ but overbalanced $C_{h_{\alpha}}$. The over-all effect was a reduction in hinge moments throughout the speed range investigated. Comparison with data for the plain flap shows that the positive increment in $C_{h_{\delta}}$ provided by the paddle balance was almost constant with Mach number, varying only from about 0.006 to 0.007. At subsonic Mach numbers the paddle balance appears to be about the right size for balance, since $C_{h_{\delta}} \approx 0$. However, at $M > 0.93$ there was a large increase of hinge moments associated with the plain flap, which indicated that at $M = 1.10$, paddles of approximately twice the size investigated would be necessary to obtain $C_{h_{\delta}} = 0$. The variation of $C_{h_{\alpha}}$ with Mach number for the paddle-balanced control was similar to that obtained for the plain flap except for absolute value. The paddle balance gave a positive increment in $C_{h_{\alpha}}$ which varied from 0.0033 at $M = 0.7$ to 0.0052 at $M = 1.1$, resulting in positive values of $C_{h_{\alpha}}$ throughout the Mach number range tested. It should be noted that positive values of $C_{h_{\alpha}}$ would make the control forces heavier in maneuvers.

Lift Characteristics

The lift effectiveness parameter C_{L_δ} for the plain flap (fig. 15) was almost constant as Mach number was increased up to $M = 0.90$; between $M = 0.90$ and $M = 1.0$, C_{L_δ} decreased; above $M = 1.0$, C_{L_δ} was generally constant. The decrease in C_{L_δ} at $M = 0.90$ was probably caused by the wing's reaching the critical Mach number region. The addition of the paddle balance affected C_{L_δ} only slightly at Mach numbers up to $M = 0.85$, but critical flow conditions probably caused by the presence of the paddles caused the critical Mach number effects to occur sooner.

The parameter C_{L_α} was similar for both the plain flap and the flap with paddle balances. The addition of the paddle balance caused the abrupt increase of C_{L_α} in the critical Mach number region, $M = 0.90$, to occur sooner.

Rolling-Moment Characteristics

The control effectiveness parameter C_{l_δ} for the plain control (fig. 16) was constant with Mach number up to $M = 0.90$. Above $M = 0.90$, C_{l_δ} decreased with further increase in Mach number. The addition of the paddle balance to the control had little effect on the rolling effectiveness of the control.

CONCLUDING REMARKS

An investigation was made at transonic speeds to determine the aerodynamic characteristics of a wing with quarter-chord line swept back 45.58°, an aspect ratio of 3, a taper ratio of 0.5, and an NACA 64A010 airfoil section measured in a plane at 45° to the plane of symmetry. Tests were made with a full-span flap-type control with and without a paddle balance. The data indicated that a paddle balance is capable of appreciably reducing C_{h_δ} throughout the speed range investigated. Although C_{h_α} became positive with the addition of the paddle balance, the over-all effect on the control hinge moments was a reduction in control force. The lift and rolling-moment parameters were only slightly affected by the addition of the paddle balance. It is recommended that further study of paddle balances on a large-scale model be made to evaluate the effect of variables such as paddle size, shape, and location.

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REFERENCES

1. Lockwood, Vernard E., and Fikes, Joseph E.: Aerodynamic Characteristics at Transonic Speeds of a Tapered 45° Sweptback Wing of Aspect Ratio 3 Having a Full-Span Flap-Type Control. Transonic-Bump Method. NACA RM L51F06a, 1951.

2. Donlan, Charles J., Myers, Boyd C., II, and Mattson, Axel T.: A Comparison of the Aerodynamic Characteristics at Transonic Speeds of Four Wing-Fuselage Configurations as Determined from Different Test Techniques. NACA RM L50H02, 1950.

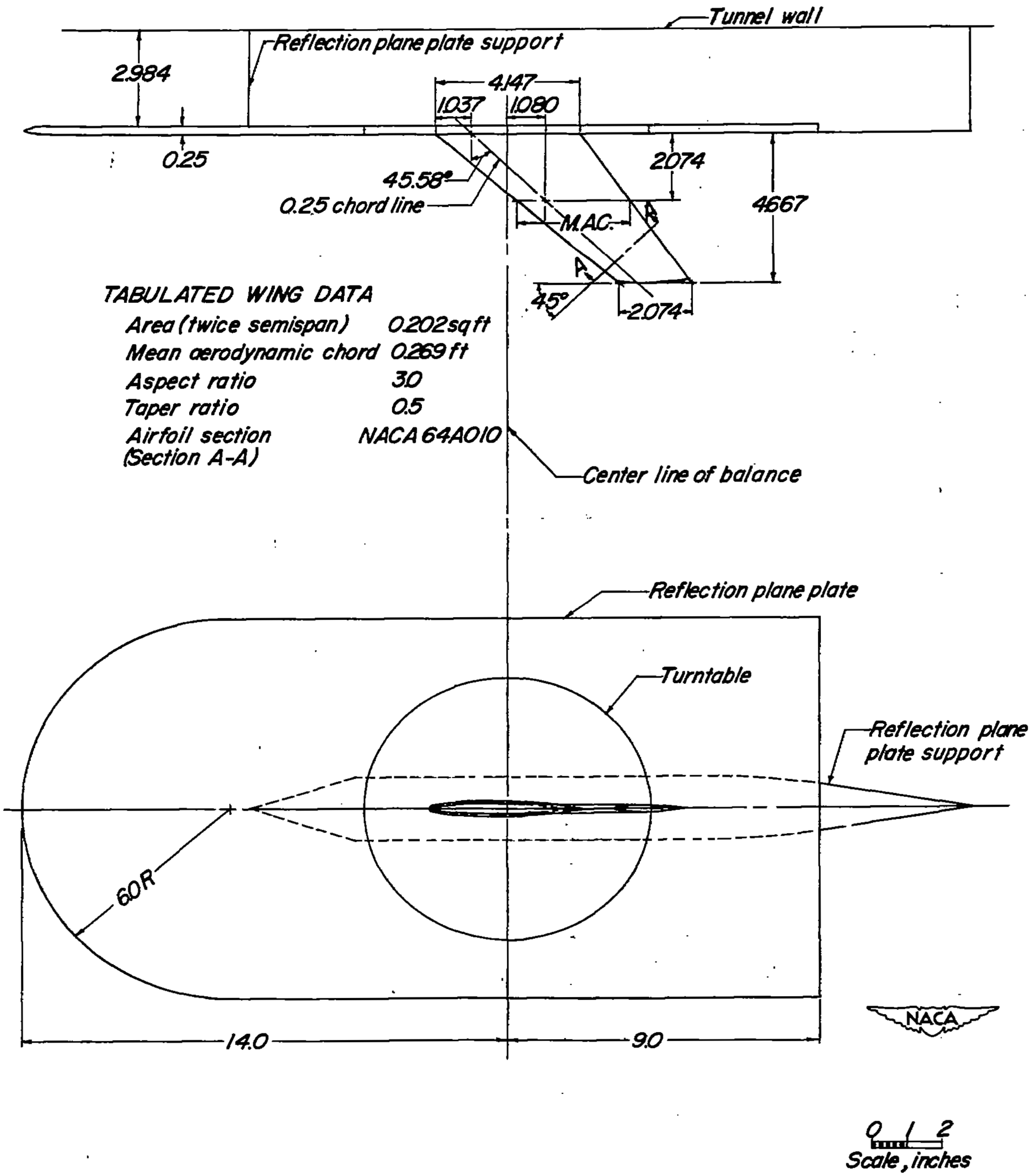

Figure 1.- General arrangement of model mounted on side-wall reflection plane.

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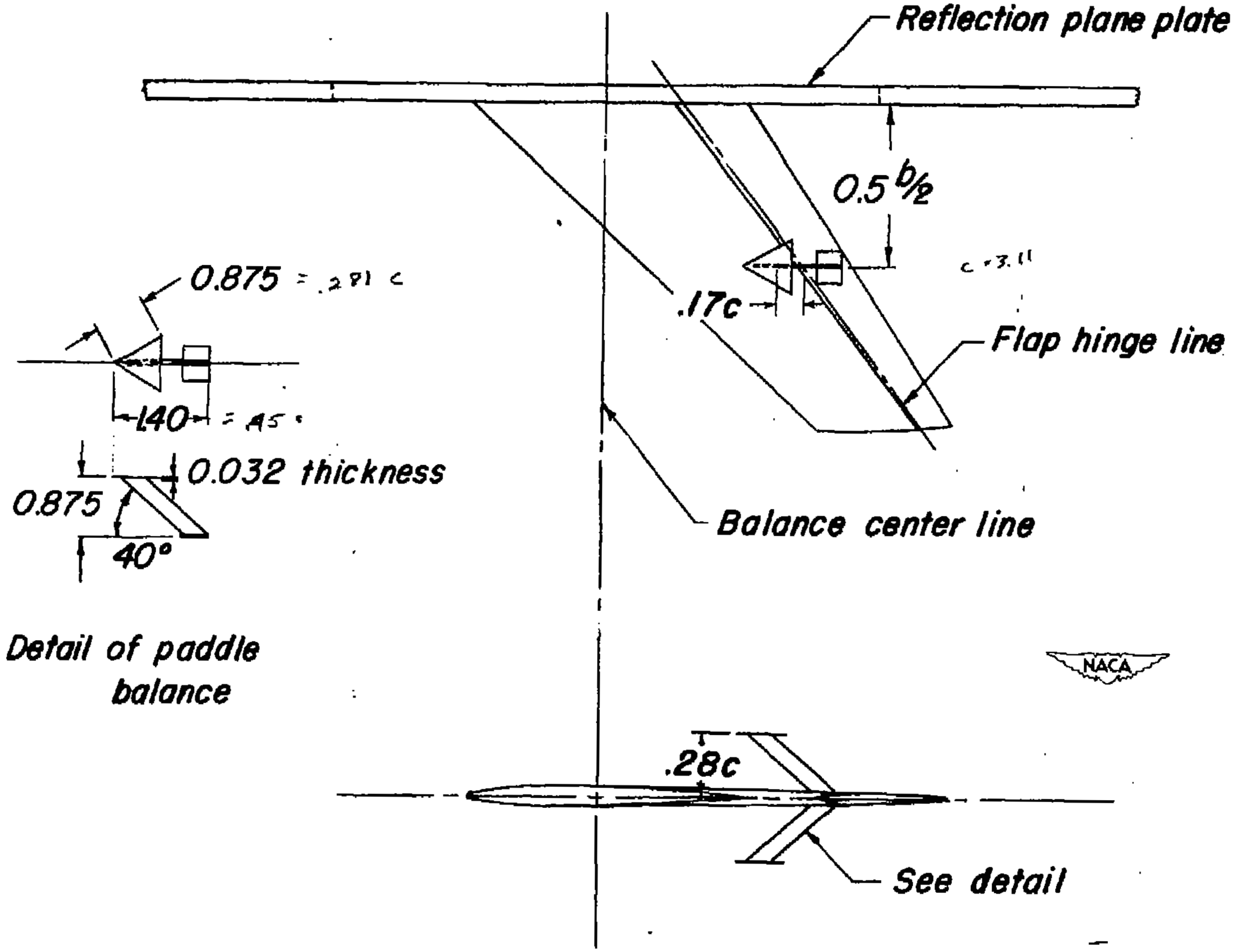

Figure 2.- Details of paddle balance.

[redacted]

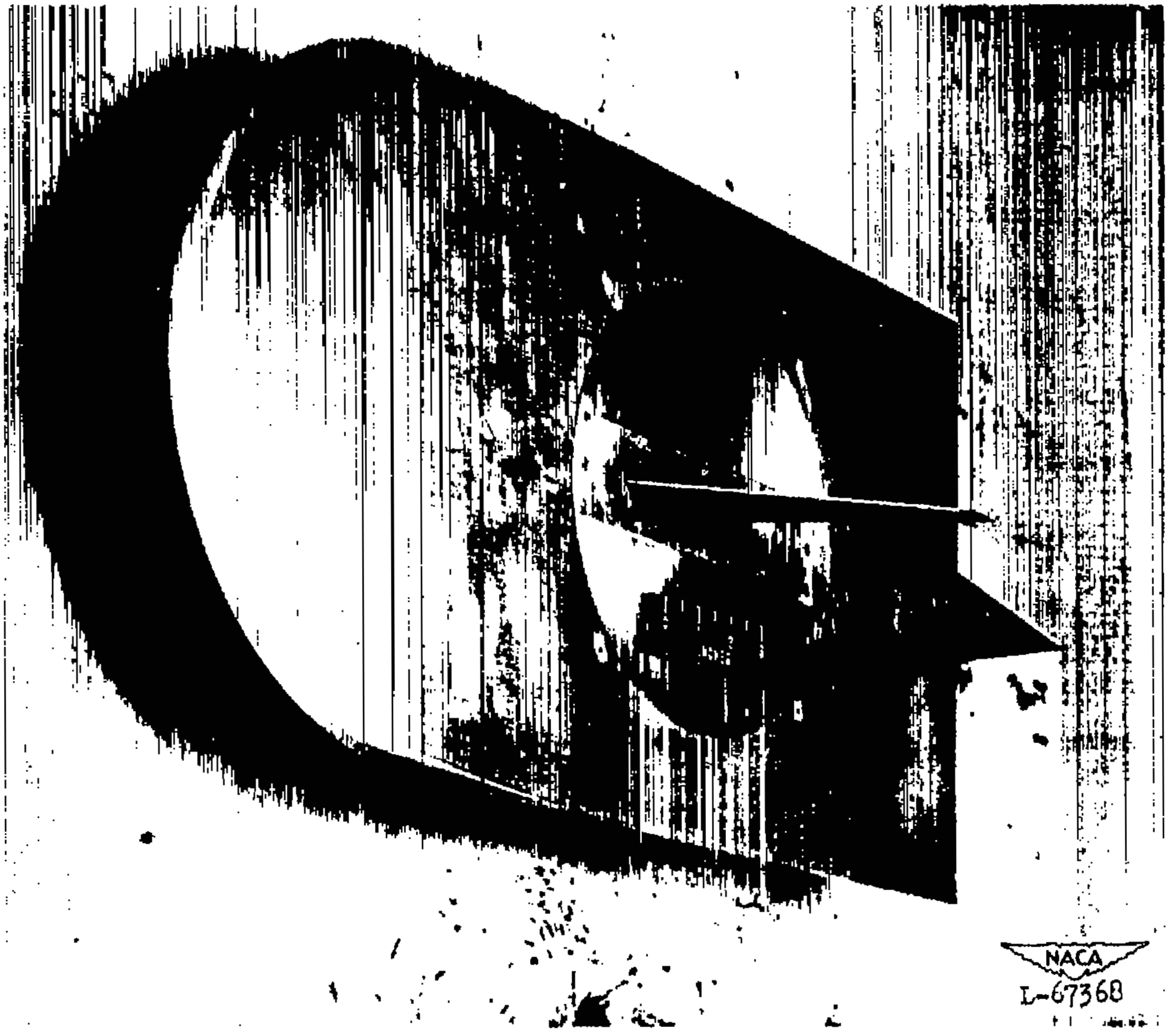

Figure 3.- Typical model setup on reflection plane in the Langley high-speed 7- by 10-foot tunnel.

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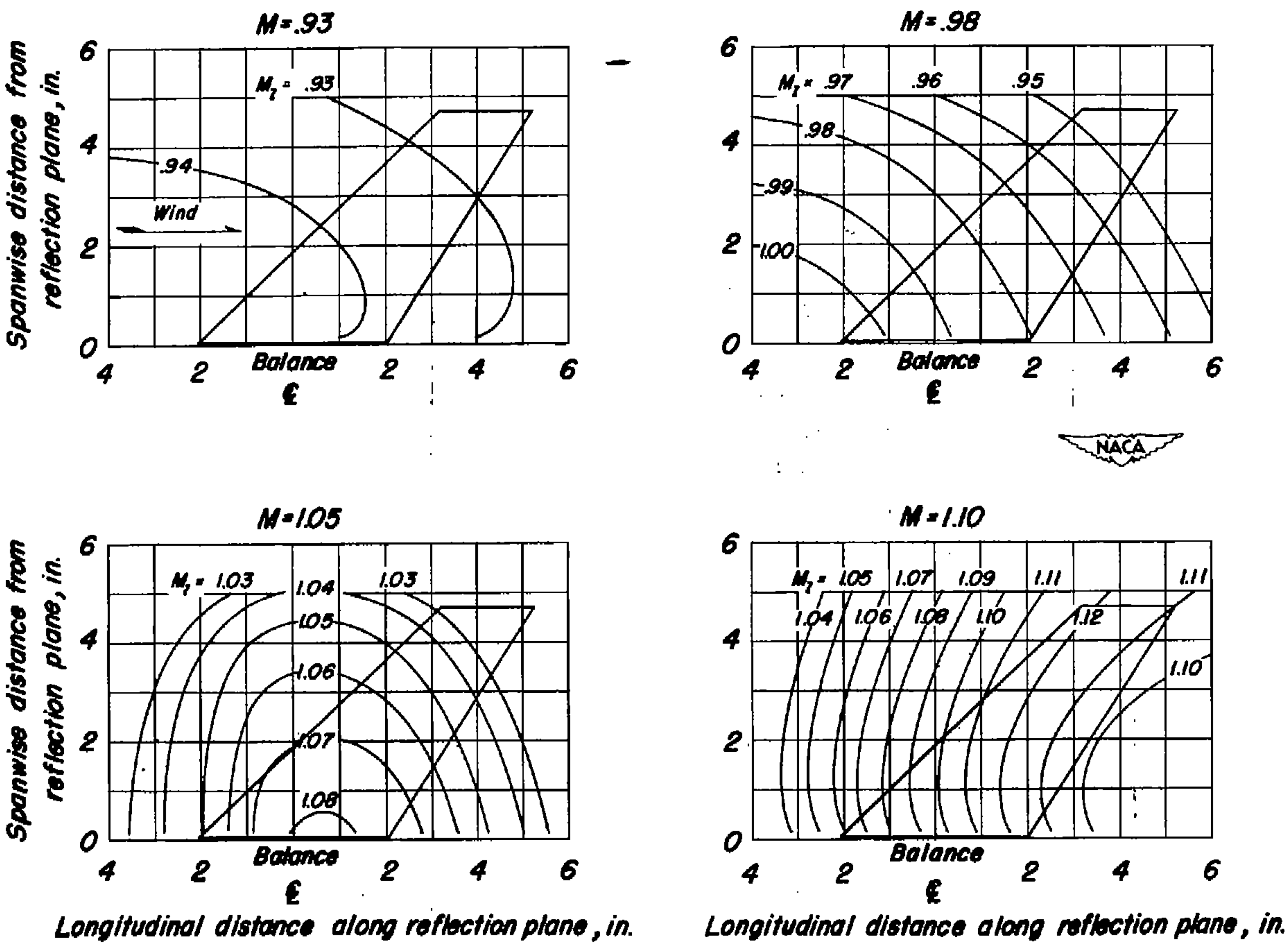

Figure 4.- Typical Mach number contours over the side-wall reflection plane in region of model location.

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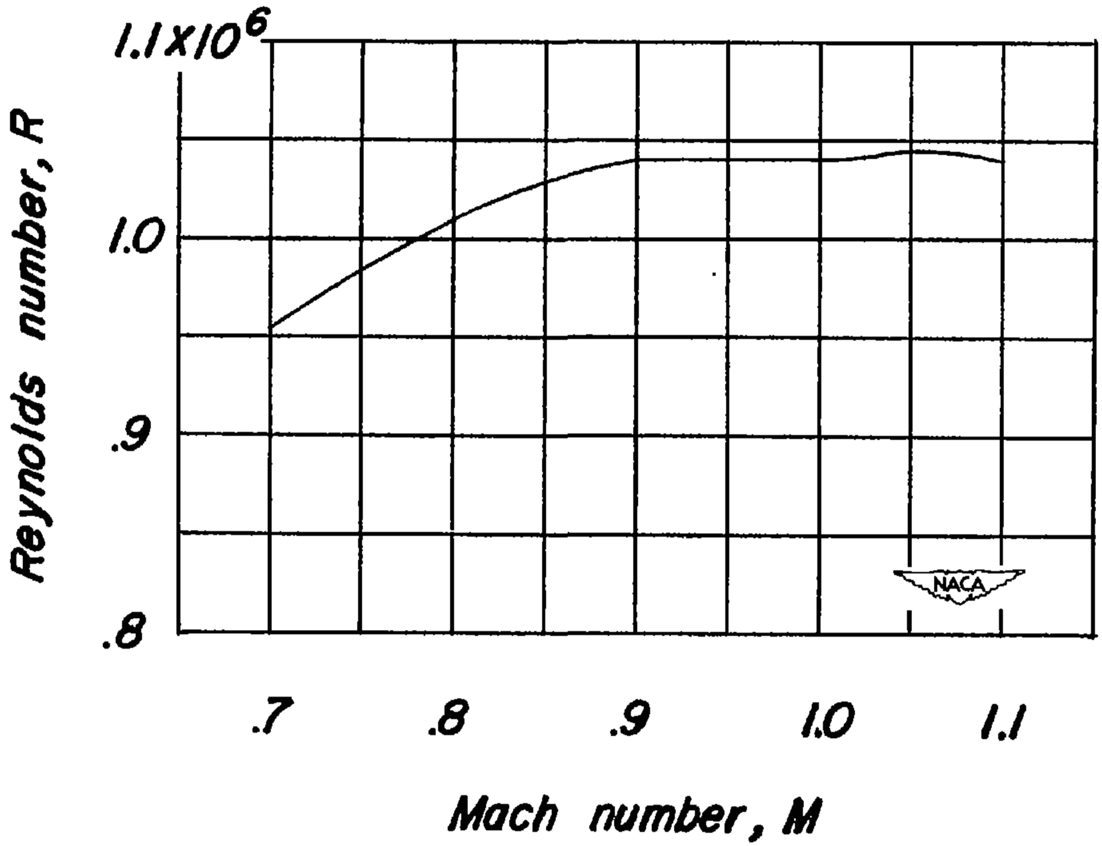

Figure 5.- Variation of average Reynolds number with Mach number through the transonic speed range.

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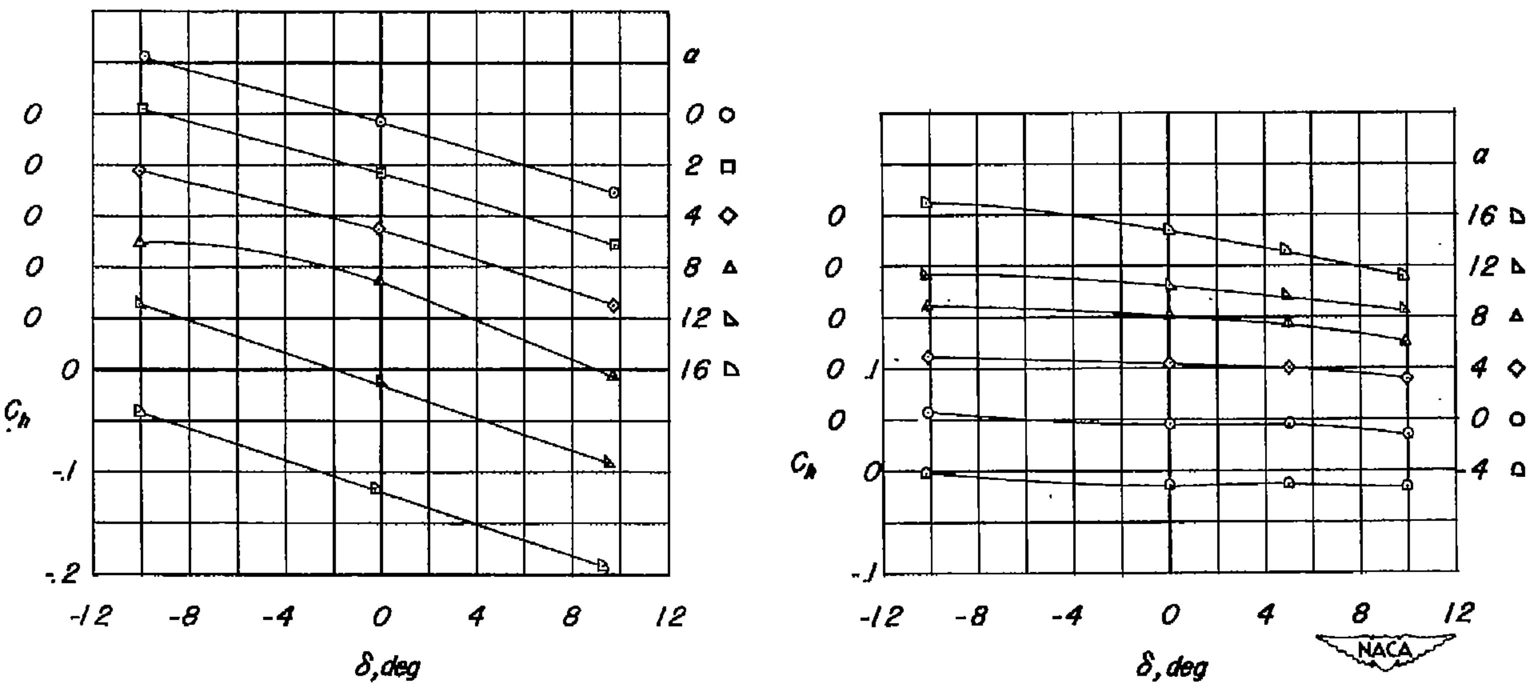
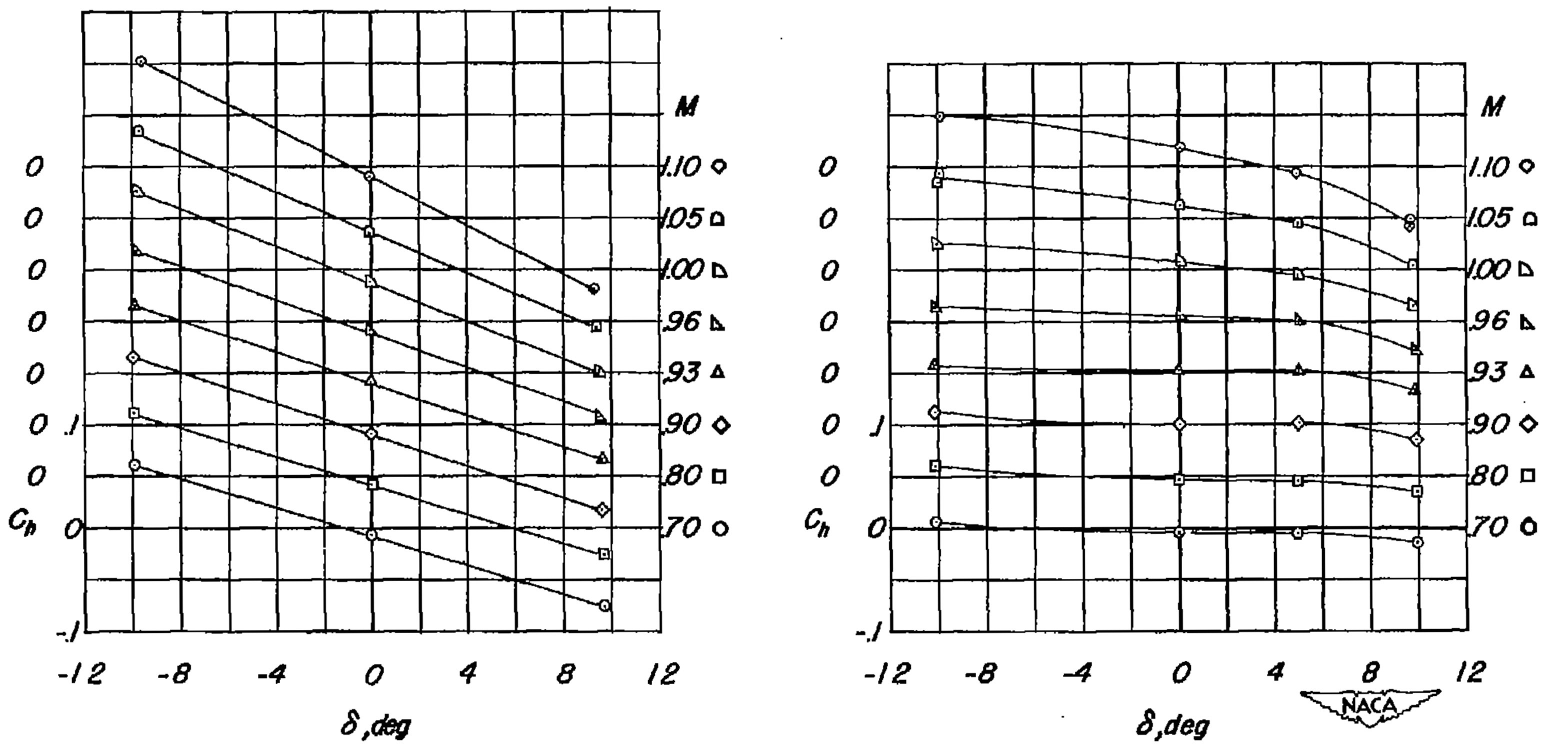


(a) Plain flap.

(b) Flap with paddle balance.

Figure 6.- Variation of control hinge moment with control deflection for various angles of attack. M = 0.70.

[redacted]



(a) Plain flap.

(b) Flap with paddle balance.

Figure 7.- Variation of control hinge moment with control deflection for various Mach numbers. $\alpha = 0^{\circ}$.

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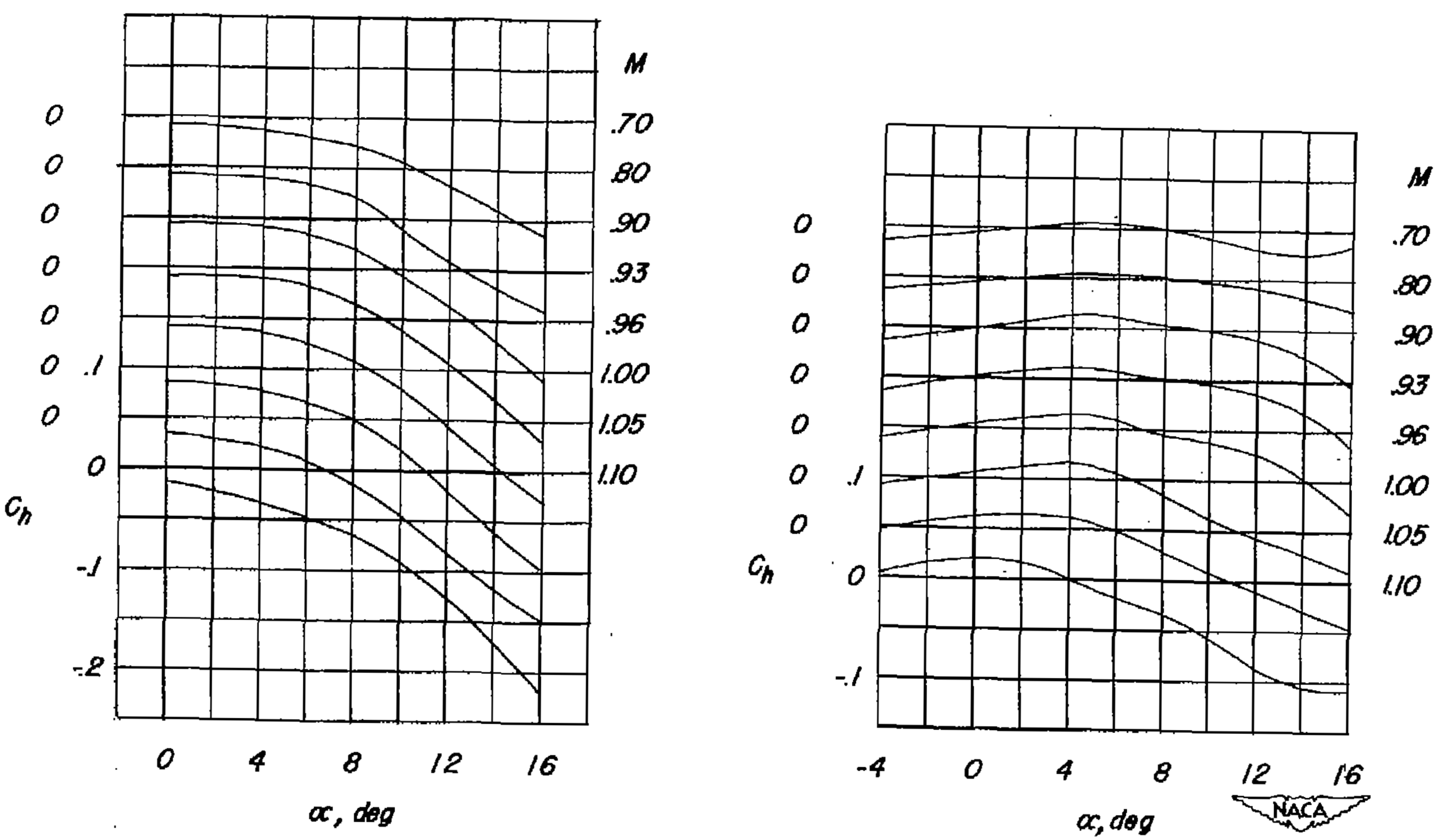


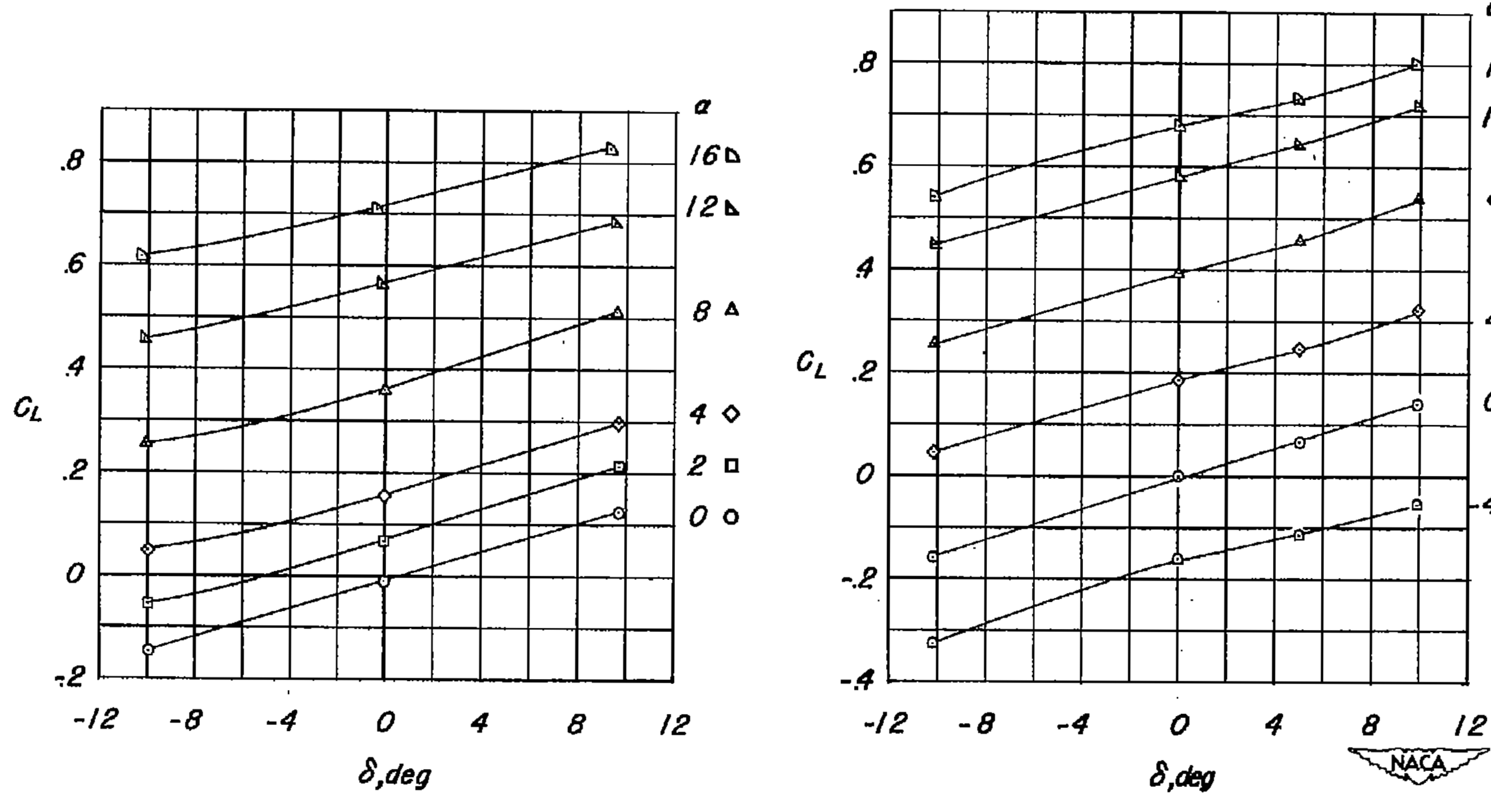
(a) Plain flap.

(b) Flap with paddle balance.

Figure 8.- Variation of control hinge moment with angle of attack for various Mach numbers. $\delta = 0$.

[redacted]

[redacted]

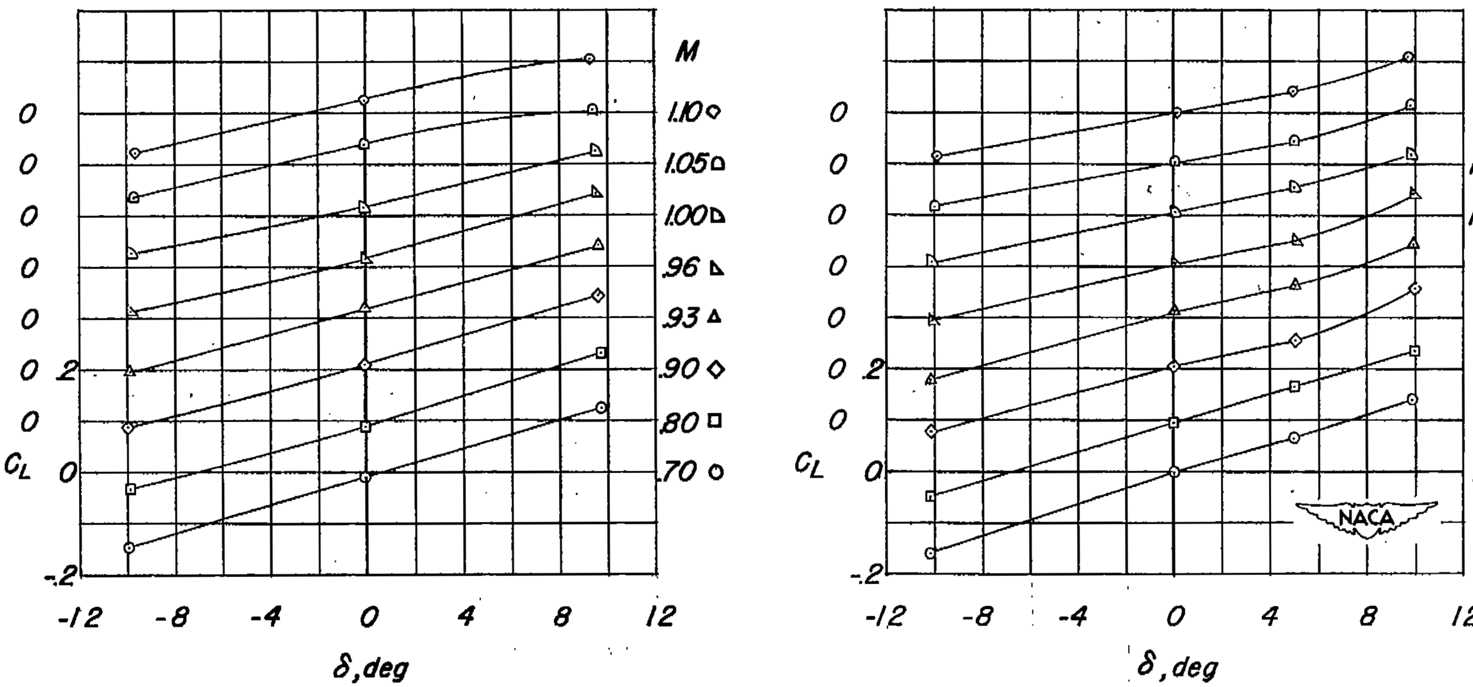


(a) Plain flap.

(b) Flap with paddle balance.

Figure 9.- Variation of lift with control deflection for various angles of attack. M = 0.70.

[redacted]



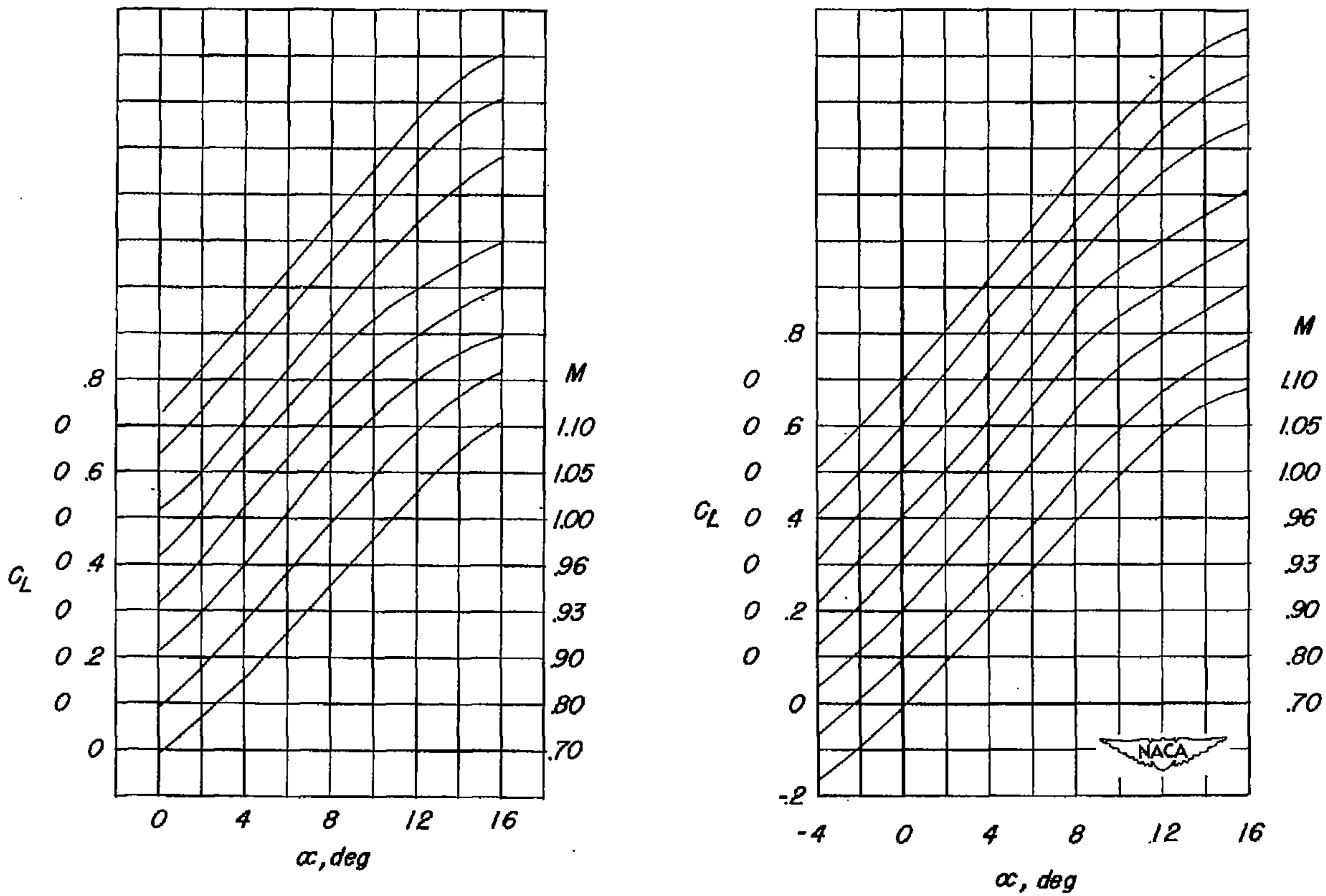
(a) Plain flap.

(b) Flap with paddle balance.

Figure 10.- Variation of lift with control deflection for various Mach numbers. $\alpha = 0^{\circ}$.

[redacted]

[redacted]



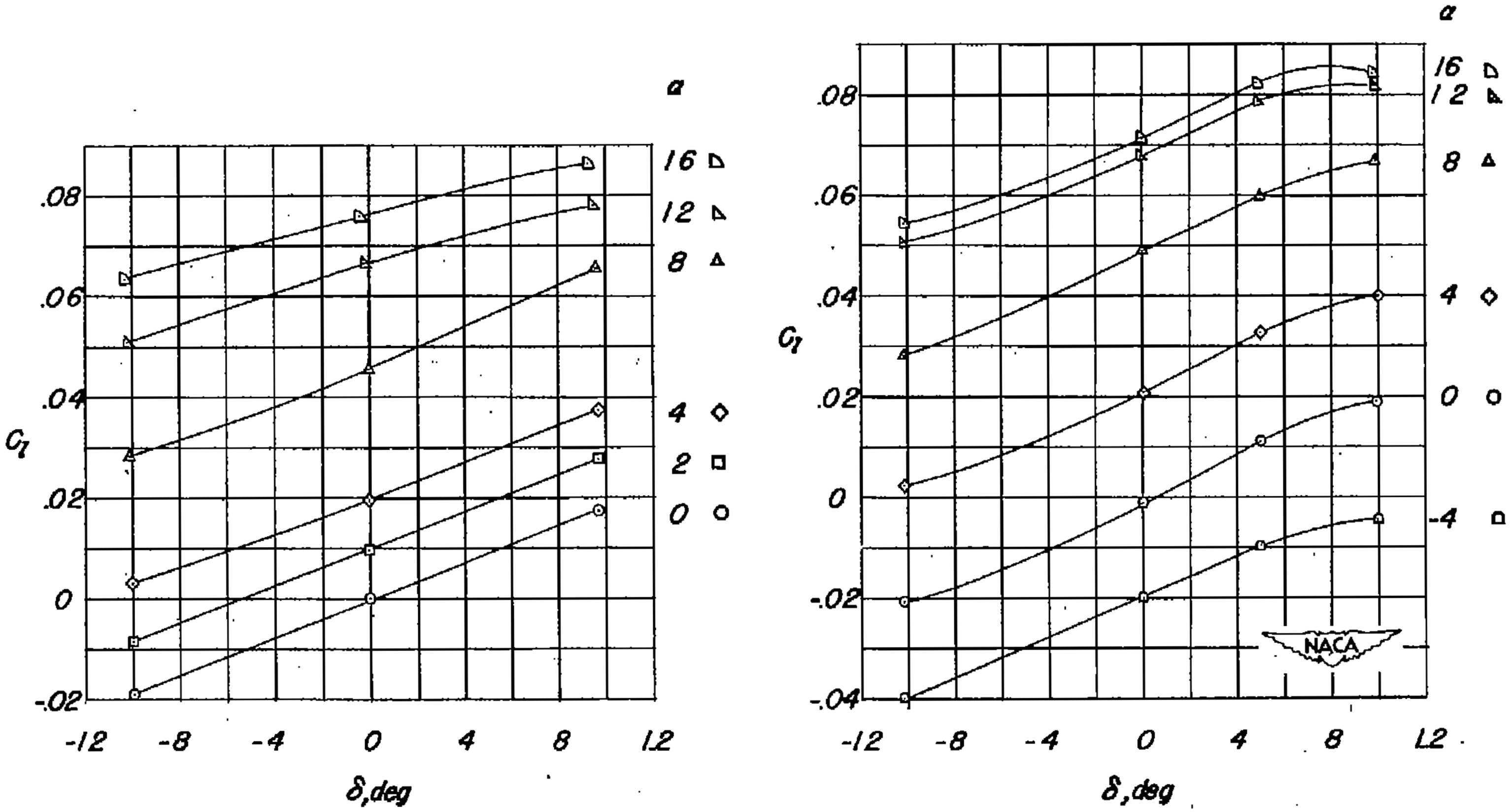
(a) Plain flap.

(b) Flap with paddle balance.

Figure 11.- Variation of lift with angle of attack for various Mach numbers. $\delta = 0$.

[redacted]

[redacted]



(a) Plain flap.

(b) Flap with paddle balance.

Figure 12.- Variation of gross rolling moment with control deflection for various angles of attack. M = 0.70.

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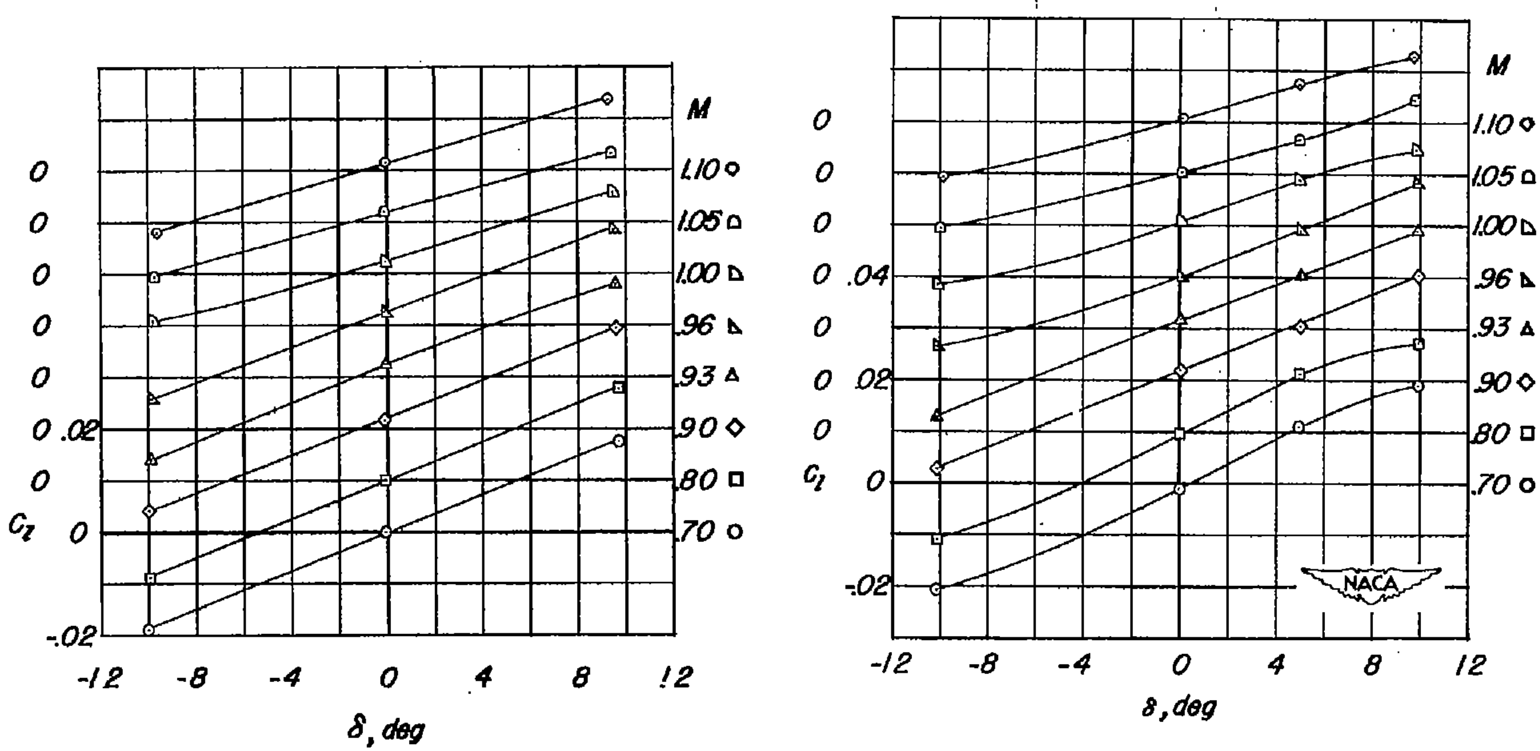
[redacted]



(a) Plain flap.

(b) Flap with paddle balance.

Figure 13.- Variation of gross rolling moment with control deflection for various Mach numbers. $\alpha = 0^{\circ}$.

[redacted]

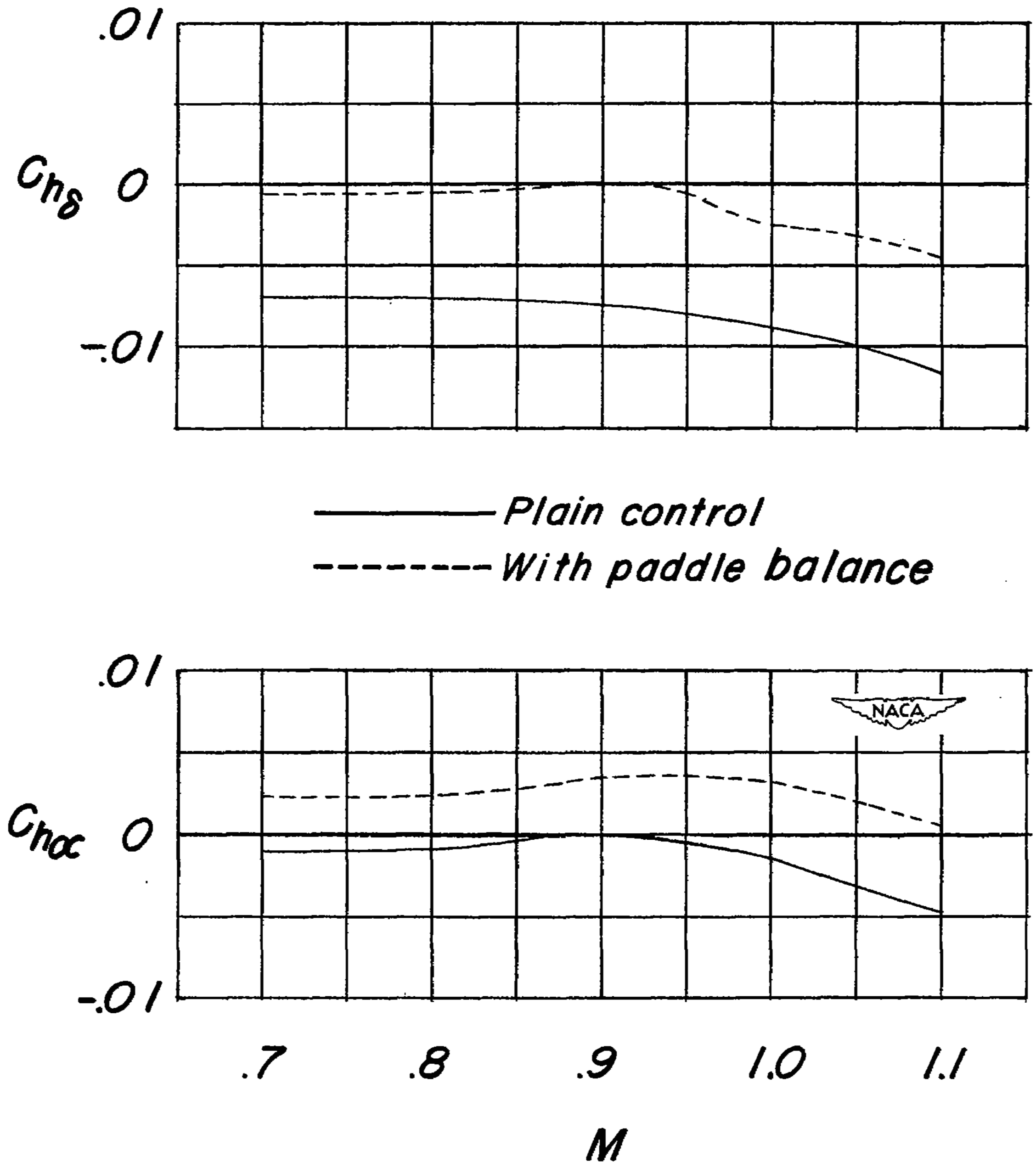


Figure 14.- Variation of the parameters C_{h_α} and C_{h_δ} with Mach number.

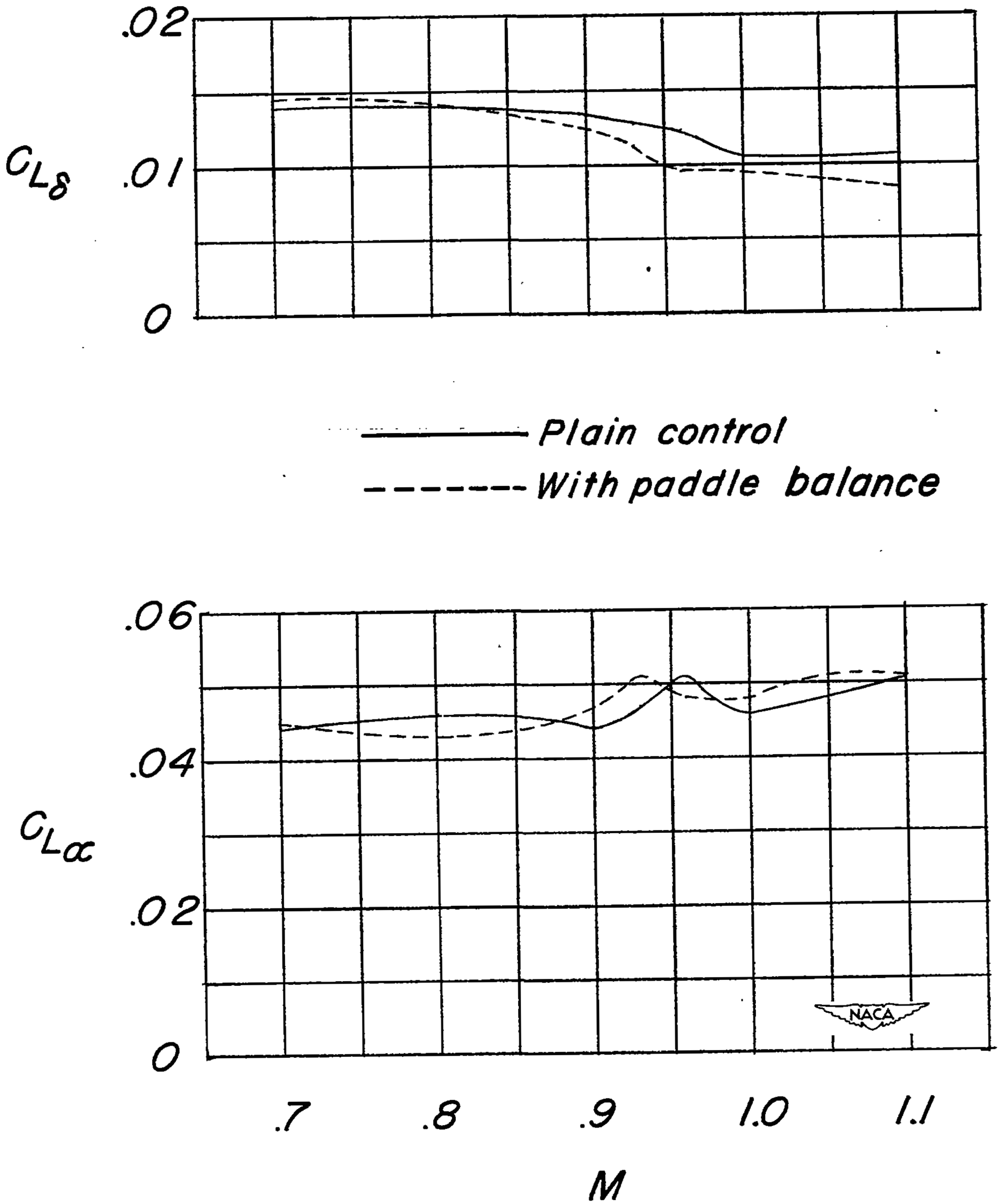


Figure 15.- Variation of the parameters C_{L_α} and C_{L_δ} with Mach number.

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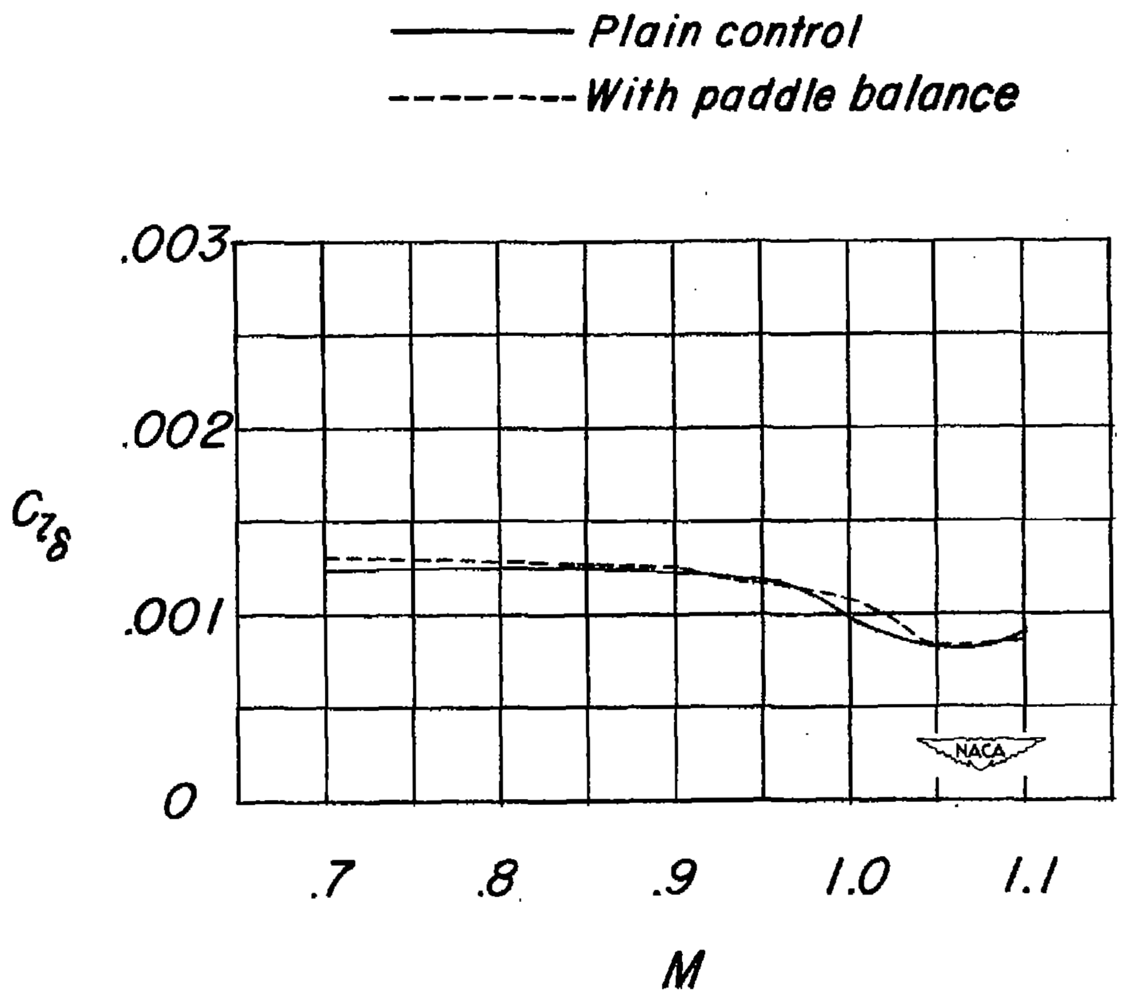

Figure 16.- Variation of the parameter C_{l_δ} with Mach number.

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